Standards and Guidelines for the Use of Wood Ash as a Liming Material for Agricultural Soils

July 2002

Pub. No: T/666
ISBN: 0-7785-2280-6 (Printed Edition)
ISBN: 0-7785-2281-4 (On-line Edition)
Web Site: http://www.gov.ab.ca/env/

Comments, questions, or suggestions on the *Standards and Guidelines for the Use of Wood Ash as a Liming Material for Agricultural Soils* can be directed to:

Science and Standards Branch
Alberta Environment
4th Floor Oxbridge Place
9820-106th Street
Edmonton Alberta T5K 2J6
Phone: (780) 427-5883
Fax: (780) 422-4192

Additional copies may be obtained by contacting:

Information Centre
Alberta Environment
Main Floor, Great West Life Building
9920 – 108th Street
Edmonton Alberta T5K 2M4
Phone: (780) 944-0313
Fax: (780) 427-4407
Email: env.infocent@gov.ab.ca

Summary

These standards and guidelines are intended for operations involving the use of energy system wood ash as a liming material for agricultural soil. General information on wood ash is presented as well as the regulatory requirements for generators and recommended practices for land managers.

Wood ash improves the pH of acidic soils in a manner similar to the use of agricultural lime. Research studies have demonstrated significant increases in crop yields resulting from this pH buffering.

These standards and guidelines are designed to ensure that the use of wood ash as a liming material is conducted in a manner that provides for the protection of human health, the environment and long-term soil productivity.

Generators of wood ash who obtain approval to offer wood ash for use as a liming material will be required to meet the conditions of their approval. The approval will include the requirement to meet the conditions in Section 2 of this document. Applicators and land managers accepting these materials are responsible for ensuring that the materials are applied and handled in an environmentally sound manner. The recommended practices contained in Section 3 of these guidelines are a means of ensuring that these objectives are met.

These standards and guidelines apply only to energy recovery system wood ashes. They do not apply to ash generated from other types of burners, such as teepee (beehive) burners or silo (olivine) burners. These standards and guidelines only cover application of energy recovery system wood ash to agricultural soils under cultivation and do not apply to pasture lands or forested areas.

Note to Users

The following information on the use of wood ash as a liming material is provided as a general note to users:

1. Wood ash consists primarily of the inorganic portion of wood as well as some organic matter, usually in the form of elemental carbon (charcoal). The calcium carbonate equivalence (CCE) of wood ash has been demonstrated to improve the productivity of acid soils by increasing soil pH.
2. These standards and guidelines have been developed for ash generated by energy recovery systems. Ash generated from other types of burners, such as teepee (beehive) burners or silo (olivine) burners, may not be used as a liming material on agricultural land.
3. These standards and guidelines are directed at the use of energy recovery system wood ash as a liming agent for agricultural soils under cultivation. They do not apply to pasture lands or forested areas.
4. Generators must ensure that their wood ash is of the required quality before offering it for use as a liming material.
5. Land managers are responsible for the quality and productivity of their lands. To ensure soil quality and productivity are maintained and improved, soil that is to receive wood ash should be characterized by the applicator or land manager according to the recommendations outlined in section 3.2 of these guidelines.
6. For maximum benefit, the applicator or land manager should determine the application rate of wood ash in accordance with section 3.3
7. Please refer to sections 3.4 and 3.5 for further instructions to land managers on the stockpiling, application and incorporation of these materials.
8. The generator and applicator must comply with all requirements of the Environmental Protection and Enhancement Act, its Regulations and approvals, and all other applicable laws. If there are any conflicts between this guideline and the Environmental Protection and Enhancement Act or Regulations, then the Act or Regulations take precedence.

TABLE OF CONTENTS

Summary i
Note to Users ii
1.0 Introduction 1
1.1 Background 1
1.2 Wood Ash and the Forest Products Sector in Alberta 1
1.3 Objectives 2
1.4 Environmental Protection and Enhancement Act 2
2.0 Requirements for Generators 3
2.1 Definitions 3
2.2 Energy Recovery System Fuel Restrictions 3
2.3 Wood Ash Characterization 3
2.4 Wood Ash Control Limits 5
2.5 Record Keeping 5
3.0 Recommended Practices for Land Managers 6
3.1 Definitions 6
3.2 Soil Sampling and Analysis 6
3.3 Determining Rate of Application 7
3.4 Wood Ash Storage 8
3.5 Application and Incorporation 9
4.0 Technical Information 10
4.1 Wood Ash Composition 10
4.2 Control Limits and Application Rates 12
5.0 References 13

TABLES

Table 1.1: Alberta facilities using wood residues for energy production. 1
Table 2.1: Testing requirements for wood ash generators 4
Table 2.2: Wood ash control limits for metals, hydrocarbons and moisture 5
Table 4.1: Summary of wood ash characteristics 10

1.0 Introduction

1.1 Background

Wood is comprised mainly of organic matter with small amounts of inorganic material. This inorganic material is the result of trees absorbing minerals from soil. When wood is burned, the organic portion is converted to CO_2 and water while the inorganic portion remains as ash.

The forest products and energy production sectors in Alberta utilize wood residues (i.e. bark, sawdust, etc.) for energy production. The combustion of these residues produces significant quantities of ash that must be appropriately managed.

Wood ash improves the pH of acidic soils in a manner similar to agricultural lime. Research studies have demonstrated significant increases in crop yields resulting from this pH adjustment. To achieve the environmental protection required under the Environmental Protection and Enhancement Act (EPEA), the standards and guidelines in this document have been developed using accepted risk assessment methodology.

1.2 Wood Ash and the Forest Products Sector in Alberta

The forest products sector in Alberta produces wood residues in the form of bark, sawdust, small ends and pieces from the incoming timber. In a number of operations these residues are burned to provide energy, resulting in the production of residual ash.

In 2001, wood residues were used for energy production at 18 forest products and related operations (Table 1.1). These operations generate almost 170,000 metric tonnes of wood ash annually in Alberta. This number is expected to grow in the future, as the use of wood residues and other "bio-fuels" becomes a more standardized practice.

Table 1.1: Alberta facilities using wood residues for energy production.

	Number of Facilities	Wood ash Production (tonnes/year)
OSB Operations	7	80 000
Kraft pulp mills	4	60 000
Lumber	2	4000
Laminated Veneer Lumber and Medium Density Fibre Board	2	4000
Biomass to Energy Plants[1]	3	20 000
Total	18	168 000

[1] This included two wood residue cogeneration plants and one peat cogeneration plant

1.3 Objectives

These standards and guidelines describe environmental controls for the use of wood ash as a liming material that will:

1) ensure that the wood ash is of suitable quality for use as a liming material;
2) ensure this use of wood ash is conducted in a manner that protects human health and the environment,
3) establish practices that will ensure that land application of wood ash is used to improve soil productivity, and
4) provide wood ash generators, applicators, and land managers with an explanation of how these guidelines fit with the general requirements of Alberta Environment and the Alberta Environmental Protection and Enhancement Act, R.S.A 2000, c.E-12.

Note: The information provided is an integration of technical and regulatory information, and applies only to the use of wood ash as an agricultural liming material.

1.4 Environmental Protection and Enhancement Act (EPEA)

The use of wood ash as a liming material has demonstrated beneficial effects on acid soil productivity. Wood ash is not a waste if it:

a) has been characterized in accordance with Section 2.3 of these standards and guidelines,
b) meets the Control Limits specified in Table 2.2 of these standards and guidelines, and
c) is being offered for use as a liming material.

Generators of wood ash are required to meet the conditions of their operating approval under EPEA. If generators wish to offer wood ash as a liming material but their operating approval does not allow the practice, they must apply to Alberta Environment for an amendment. An application for approval amendment must be prepared in accordance with the Approvals and Registrations Procedure Regulation (113/93 and 216/96) under EPEA. The approval will require the generator to meet the provisions in Section 2 of this document.

Failure to follow required and recommended procedures may cause an adverse effect to the environment and therefore a contravention of EPEA that may result in regulatory enforcement action.

If there are any inconsistencies between the contents of these standards and guidelines and EPEA or its Regulations, then EPEA and its Regulations take precedence.

2.0 Requirements for Generators

Generators offering wood ash for use as a liming material must comply with the Environmental Protection and Enhancement Act, R.S.A. 2000, c.E-12 and its associated regulations and the requirements of this section:

2.1 Definitions

All definitions in the Interpretation Act, R.S.A. 2000, c.I-8 and in the Environmental Protection and Enhancement Act, R.S.A. 2000, c.E-12, as amended, and its regulations apply except where expressly defined in this standards and guidelines document. In Section 2.0 (Requirements for Generators) of this standards and guidelines document, the following definitions apply:

a) "agricultural soil" means soil cultivated and used for the growth of cereal crops, oil seed, pulse, forages and sod, but does not include soil under permanent pasture;

b) "energy recovery system" means a system that is designed to burn wood residues and recover the heat of their combustion;

c) "generator" means the person responsible for the energy recovery system;

d) "liming material" means material used to increase the pH of agricultural soil;

e) "wood ash" means the product of wood residue combustion collected or retained by an energy recovery system;

f) "wood residues" means byproducts originating from the production of wood products such as, but not limited to, pulp, paper, lumber, panel board and value added products. These byproducts include, but are not limited to, bark, sawdust, sander-dust, trim ends, log yard wastes, primary or secondary pulp mill wastewater treatment sludge, pin and off grade chips and other parts of the timber.

2.2 Energy Recovery System Fuel Restrictions

2.2.1 The wood residues used as fuel for the energy recovery system shall not be mixed with more than 5% by weight of any other non-hazardous substance.

2.2.2 Wood products or wood residues treated with preservatives shall not be used as, or mixed with, the fuel source for the energy recovery system.

2.3 Wood Ash Characterization

2.3.1 Wood ash offered by the generator as a liming material shall consist only of particles collected from an energy recovery system.

2.3.2 Wood ash that is to be offered as a liming material shall be monitored in the following manner:

a) Prior to making wood ash available as a liming material for the first time, the generator must conduct an initial characterization of the ash for all parameters listed in Table 2.1;
b) This initial characterization shall be conducted on:
   i) three representative samples of wood ash for all parameters except polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans, and
   ii) one representative sample of wood ash for polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans;
c) After initial characterization of the wood ash, the generator shall measure the wood ash for all the parameters listed in Table 2.1 in the following frequencies:
   i) once every four months during operation of the energy recovery system for all parameters except polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans, and
   ii) at least once per year during operation of the energy recovery system for polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans;
d) A generator that is a kraft pulp mill must monitor for polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans prior to making the wood ash available for land application if the wood ash was produced by the burning of wastewater treatment plant sludges; and
e) All analyses must be carried out using the test methods in Table 2.1

Table 2.1: Testing requirements for wood ash generators

Parameter	Test Method
Metals:	
Cadmium	U.S. EPA 3050 or 3051 and 6010 or 6020
Zinc	U.S. EPA 3050 or 3051 and 6010 or 6020
Boron (Hot Water Soluble)	McKeague 4.61 or 4.62 or 4.63 or Carter 12.2
Hydrocarbons	
Benzo(a)pyrene	U.S. EPA 8270
Naphthalene	U.S. EPA 8270
Polychlorinated Dibenzo-*p*-dioxins and Polychlorinated Dibenzofurans	U.S. EPA 8280 or 8290
Others	
Acid Neutralizing Value	AOAC 955.01
Moisture content (as-received basis)	ASTM D2974 (Test Method A)

Table 2.2: Wood ash control limits for metals, hydrocarbons and moisture

Parameter	Maximum Level (mg/kg, except where noted)
Metals	
Cadmium	46
Zinc	5500
Boron (Hot Water Soluble)	43
Hydrocarbons	
Benzo(a)pyrene	4
Naphthalene	4
Polychlorinated dibenzo-*p*-dioxin and Polychlorinated dibenzofurans	27 ng/kg (2,3,7,8 Tetrachlorodibenzo-*p*-dioxin equivalent)
Moisture (as-received basis)	Minimum Level 1%

2.4 Wood Ash Control Limits

2.4.1 Wood ash that is offered as a liming material must meet the control limits listed in Table 2.2.

2.5 Record Keeping

2.5.1 A generator that offers wood ash as a liming material shall document and retain the following information for a minimum of 10 years:

a) the name and address of the person or company receiving the wood ash from the generator,
b) the quantity of wood ash provided to the person or company receiving the wood ash,
c) the date of the transfer of the wood ash to the person or company receiving the wood ash, and
d) verification that the person or company receiving the wood ash has been provided with a copy of Section 3.0 of this standards and guidelines document.

2.5.2 A generator shall retain copies of the analytical results for the characterization required in section 2.3.2 for a minimum of 10 years.

2.5.3 The information required to be maintained in accordance with sections 2.5.1 and 2.5.2 shall be kept at the facility where the wood ash was generated.

2.5.4 The information required to be maintained in accordance with sections 2.5.1 and 2.5.2 shall be made available to a representative of Alberta Environment upon request.

3.0 Recommended Practices for Land Managers

Wood ash that meets the requirements in Section 2.0 of these standards and guidelines may be used as a liming material to raise the pH of acid soils. To ensure the ash is used in a manner that protects the environment, human health and the productivity of the land, certain precautions should be taken. This section outlines those recommended practices that applicators and land managers of wood ash should follow to maintain soil quality and productivity as well as preventing any negative environmental impact.

To determine the appropriate application rate for wood ash to soil, the steps outlined in Sections 3.2 to 3.3 should be taken.

3.1 Definitions

The following terms are defined to ensure clarity for the purposes of Section 3.0 (Recommended Practices for Land Managers) of this document:

a) "agricultural soil" means soil cultivated and used for the growth of cereal crops, oil seed, pulse, forages and sod, but does not include soil under permanent pasture;

b) "applicator" means the corporate entity or individual who applies the wood ash to agricultural soil;

c) "EPEA" means the Environmental Protection and Enhancement Act;

d) "land application" means the spreading of wood ash on the soil surface and its incorporation into the soil;

e) "land manager" means the person responsible for the management and control of the lands to which the wood ash will be applied;

f) "liming material" means material used to increase the pH of agricultural soil;

g) "stockpiling" means the storage of wood ash for a period longer than 30 days;

h) "wellhead protection zone" means a zone of restricted development surrounding a public water supply well or well field;

i) "wood ash" means the product of wood residue combustion collected or retained by an energy recovery system;

3.2 Soil Sampling and Analysis

3.2.1 Soil sampling should be conducted on the receiving field using recognized soil sampling procedures. The following sources provide appropriate soil sampling and analysis procedures:

- AOAC. 1990. Official Analytical Methods of the Association of Official Analytical Chemists, 15th Edition. Association of Official Analytical Chemists, Arlington, VA.
- ASTM. 2000. Annual Book of ASTM Standards. ASTM International. West Conshohocken, PA.

- Carter, M.R. (ed). 1993. Soil Sampling and Methods of Analysis. Lewis Publishers, Boca Raton, FL.
- McKeague, S.A. (ed). 1978. Manual on Soil Sampling and Methods of Analysis. Canadian Society of Soil Science.
- U.S. EPA. 1980. Test Methods for Evaluation of Solid Wastes. SW-846. United States Environmental Protection Agency.

3.2.2 The field should be divided into sampling units that are relatively homogenous in their physical and chemical characteristics. The sampling units should be based on the following:

- past crop growth patterns
- differences in crop history with respect to type of crop grown, rate of fertilization, years since the land was developed for farming, etc.
- changes in field topography
- differences in the soil with respect to texture, recent organic matter and topsoil color
- avoid sampling in old fencerows, manure and straw piles, areas where fertilizer may have been spilled and other areas not representative of the field.

Differences in characteristics among sampling units may result in different amounts of wood ash being needed to adjust pH to the desired level.

3.2.3 Composite soil samples from a depth of 0-15 cm should be obtained by randomly sampling each sampling unit at 15 to 20 locations. Each composite sample should be mixed, breaking any lumps, and allowed to air dry prior to being submitted to a soil-testing laboratory.

3.2.4 Soil samples should be analyzed for the following parameters by a soil-testing laboratory accredited for these analyses:

- Soil pH
- Lime requirement to achieve a soil pH of 6.0 and 6.5

3.2.5 Acidic soil pH is not the only soil condition that can limit crop productivity. Additional sampling depths and analytical parameters may be necessary to identify other limiting conditions.

3.3 Determining Rate of Application

3.3.1 Determine the appropriate rate of wood ash application as follows:

a) Determine the lime requirement for the receiving soils in tonnes per hectare or tons per acre (from lime requirement test in 3.2.4).

b) Determine the moisture content (in %) and acid neutralization value (expressed as calcium carbonate equivalence (CCE %)) of the wood ash. This information will be available from the generator of the wood ash.

c) Use the following formula to determine the appropriate application rate of the ash:

$$\text{Wood Ash Application Rate} = \frac{10000 \times \text{Lime Requirement}}{\text{CCE \%} \times (100 - \text{Wood Ash Moisture \%})}$$

Example: Determination of Wood Ash Application Rate

Lime Requirement = 2.8 tonnes per hectare (from field testing)

CCE of wood ash = 62% (provided by generator)

Moisture content of wood ash = 11% (provided by generator)

$$\text{Wood Ash Application Rate} = \frac{10000 \times 2.8}{62 \times (100 - 11)} = \textbf{5 tonnes per hectare}$$

3.3.2 The wood ash application rate should not exceed the rate determined using the above procedure or 15 tonnes/hectare, whichever is less.

3.3.3 Where soil testing indicates that previous wood ash applications are no longer effective in controlling soil pH, wood ash may be reapplied in accordance with 3.2 to 3.3.2, provided the total addition of wood ash from all applications does not exceed 45 tonnes/hectare.

3.4 Wood Ash Storage

3.4.1 The applicator should land-apply the wood ash as soon as possible after receiving the wood ash to avoid the need for storage at the site of application. If necessary, these materials may be stockpiled at the site of application and spread at a later date when soil conditions permit or after the crop is harvested.

3.4.2 Wood ash should not be stored on vegetated areas. If stockpiling takes place, the material should be stored on an unvegetated pad, tarp, or inside a building. If stored outside, the wood ash should be covered by tarps to prevent the off-site removal by wind or water.

3.5 Application and Incorporation

Wood ash should be applied as follows:

3.5.1 Wood ash should be applied with equipment that provides accurate and uniform distribution over the soil's surface. During application, care should be taken to ensure the wood ash does not drift beyond the area to which it is being applied.

3.5.2 The applicator should incorporate the wood ash into the soil to a depth of 15 cm within one day of land spreading.

3.5.3 Carry over of the wood ash into permanent water bodies should be prevented. Wood ash should not be applied within 50 metres of permanent water bodies or wells. Any wellhead protection areas should be considered as additional restrictions.

3.5.4 Wood ash should not be spread on frozen or snow covered soils.

3.5.5 Dust from the wood ash should be controlled to prevent the airborne release of wood ash.

4.0 Technical Information

4.1 Wood Ash Composition

During the combustion of wood residues in energy recovery systems, the organic portions are converted to carbon dioxide and water and the inorganic portions remain. Combustion efficiency depends on a number of factors including the physical make up and operating conditions of the energy system and the type or species of wood residues that are the primary fuel source.

Due to these factors, the wood ash composition can vary considerably between generators. While this was taken into consideration in the development of these guidelines, there is some commonality in ash composition. Table 4.1 summarizes the typical elemental content of wood ash.

In addition to the heavy metal composition of wood ash, several other important components are described below:

Acid Neutralizing Value

One of the main valuable properties of wood ash is its ability to increase the pH of acid soils. This is due to the presence of calcium, magnesium, potassium, and sodium oxides, hydroxides, and carbonates. Oxides initially dominate in ash originating from an energy system with high operating temperatures. When this material is exposed to moisture, the oxides convert to hydroxides. Over time, as the ash is exposed to carbon dioxide in the atmosphere, the hydroxides further convert to carbonates.

Table 4.1: Summary of wood ash characteristics[1]

Parameter	Mean (mg/kg)	Coefficient of Variation (%)
Aluminum	3800	34
Barium	1100	63
Boron (Hot Water Soluble)	38	66
Cadmium	12	65
Calcium	242,000	68
Copper	32	38
Lead	4.2	28
Magnesium	12,000	32
Nickel	24	30
Phosphorous	6000	55
Potassium	42,000	50
Sodium	4800	95
Sulphur	3530	63
Zinc	1700	75

[1] *Based upon a comparison of three mills utilizing hardwood and softwood species, as well as OSB and Kraft pulp manufacturing, with exception of hot water soluble boron, which is based on two mills, and sulphur, which is based on one mill.*

The form of calcium, magnesium, potassium and sodium in the ash, as well as the presence of other organic and inorganic compounds will affect the ability of the ash to increase soil pH. The overall ability of ash to raise pH is determined through an Acid Neutralizing Value (ANV) test. This is a ratio comparison of the neutralizing ability of ash relative to pure calcium carbonate. The results of this test are expressed as a proportion of the amount of calcium carbonate that would provide equivalent buffering (calcium carbonate equivalence (CCE)).

The CCE of ash can vary greatly from near or above 100% to as low as 30%. This factor is taken into consideration in determining the application rate for the material.

Electrical Conductivity

Electrical conductivity (EC) is an indirect measure of the concentration of dissolved salts. Excessive concentrations of soluble salts can impair plant growth by limiting the plant's ability to take up water, or through specific ion toxicities. The growth of most common agricultural crops is not impacted at EC levels below 2 dS/m. Field testing of wood ash has determined that EC is not a limiting factor in the use of ash.

Sodium Adsorption Ratio (SAR)

Sodium adsorption ratio is an indirect measure of the sodium hazard and is calculated using the values of water-soluble calcium, magnesium, and sodium obtained from analysis of a saturated paste extract. High SAR is particularly damaging to soil containing shrinking and swelling clays such as montmorillonite. High sodium can deteriorate soil structure and result in soil management problems. At a soil SAR of < 4, there is no limitation on plant growth. Values of SAR between 4 and 8 may indicate slight to moderate limitations. Field testing of wood ash has determined that SAR is not a limiting factor in the use of ash.

Organics

During the combustion process polycyclic aromatic hydrocarbons (PAHs) may form. PAHs are organic compounds that occur in ashes that have undergone incomplete combustion. Two PAHs, benzo(a)pyrene and naphthalene are listed as compounds of concern in the Canadian Environmental Quality Guidelines (CCME, 1999). The soil quality guidelines for these compounds have been taken into account in determining the wood ash control limits and application rates in Sections 2 and 3.

Chlorinated Compounds

Chlorinated organic compounds, such as dioxins and furans, are created when combustion occurs in the presence of chlorine-containing compounds such as salts. In Alberta, wood residues used as fuel sources have limited concentrations of chlorine-containing compounds.

Testing has been done on wood ash from kraft pulp mills, which use chlorine compounds in their process, and oriented strand board operations to determine the levels of dioxin and furans. While some isomers of polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans (PCDDs and PCDFs) were detected at the ppq (parts per quadrillion) levels, the 2,3,7,8 TCDD "toxic equivalence" was found to be well below provincial and national standards.

Testing for the presence of these compounds is a requirement for wood ash generators.

4.2 Control Limits and Application Rates

Application of wood ash to land must be controlled to maximize its benefit and prevent adverse effects on the environment, human health or the future fertility/sustainability of the fields to which they are applied. The substances listed in Table 2.2 have been identified as posing a potential hazard if excessive quantities of ash are applied to soil. The control limits in Table 2.2 were developed to ensure that the agricultural use of wood ash protects human health and environmental quality.

Control limits are maximum allowed concentrations in wood ash for land application. The control limits for boron, cadmium, zinc, naphthalene, and benzo(a)pyrene in Table 2.2 are set at levels that ensure their concentrations will not exceed agricultural soil quality guidelines under the maximum lifetime load of 45 t/ha allowed by this guideline. The *Alberta Tier I Criteria for Contaminated Soil Assessment and Remediation* (Alberta Environment, 1994) were used to develop the boron control limit. The *Canadian Environmental Quality Guidelines* (CCME, 1999) were used to develop the control limits for cadmium, zinc, naphthalene, and benzo(a)pyrene.

Polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans control limits were not calculated using agricultural soil guidelines. A more conservative approach was used to set a lower limit, based on the Quebec standard (Bureau de Normalisation du Québec 1997), in keeping with the concept of achieving virtual elimination of toxic, bioaccumulative compounds in the environment.

A control limit for moisture is included to promote conversion of the oxides initially present in the wood ash to hydroxides or carbonates. This precaution reduces the risk of raising soil pH to an excessive level when freshly generated ashes are applied to land.

5.0 References

Alberta Environment. 1994. Alberta Tier I Criteria for Contaminated Soil Assessment and Remediation. Edmonton, Alberta

AOAC. 1990. Official Methods of Analysis of the Association of Official Analytical Chemists, 15th edition. Association of Official Analytical Chemists, Arlington, VA.

ASTM. 2000. Annual Book of ASTM Standards, Volume 4.08: Soil and Rock (I). ASTM International. West Conshohocken, PA.

Bureau de Normalisation du Québec. 1997. Liming Materials from Industrial Processes. Amendements calciques ou magnésiens provenant de procédés industriels. NQ 0419-090.

CCME. 1999. Canadian Environmental Quality Guidelines. Canadian Council of Ministers of the Environment., Winnipeg, MB.

Carter, M.R. (ed) 1993. Soil Sampling and Methods of Analysis. Lewis Publishers, Boca Raton, FL.

McKeague, S.A. (ed). 1978. Manual on Soil Sampling and Methods of Analysis. Canadian Society of Soil Science.

Province of Alberta. Environmental Protection and Enhancement Act. 1993. Queen's Printer for Alberta.

Province of Alberta. Approvals and Registrations Procedure Regulation. 1993. Queen's Printer for Alberta.

Province of Alberta. Activities Designation Regulation. 1996. Queen's Printer for Alberta.

U.S. EPA. 1980. Test Methods for Evaluating Solid Waste, Physical/Chemical Methods. SW-846 United States Environmental Protection Agency.